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TESLA Test Cell Cryostat Support Post Thermal and Structural Analysis

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INTRODUCTION

TeV Superconducting Linear Accelerator (TESLA) cryostats consist of eight, 1-meter-long radio frequency (RF) cavity modules cryogenically connected in series with one focusing quadrupole. Each module contains one, 9-cell superconducting RF cavity operating at 1.3 GHz in a 1.8K helium bath. Individual modules are self-contained in the sense that they have their own input couplers, high order mode couplers, and tuning mechanisms. Services common to the entire cryostat consist of 70K and 4.5K thermal radiation shields, shield supply and return lines, a 1.8K helium supply line, and a gas helium return pipe. All cavity modules, the quadrupole, and cryogenic services are contained in a single 12-meter-long vacuum vessel.

The goal of the present work on TESLA is the successful fabrication and test of four complete cryostat assemblies. These cryostats will be installed in a string, cooled to operating temperature, and powered. This test will address problems which may arise when modules are installed in a tunnel environment. It will also permit testing of the basic cooling concepts, measurement of static heat losses, and measurement of the RF performance of all cavities.¹

All of the current design options utilize a post-type suspension system modeled after that developed for SSC collider dipoles. However, rather than a reentrant design like those in early SSC prototypes²⁻⁵, this support uses a single

filament wound composite tube. This latter design has recently been adopted for production SSC collider dipoles.⁶

Any successful design must be structurally adequate to meet the static and dynamic loads which occur during fabrication, shipping, installation, and operation. It must have low thermal conductivity to insulate the 1.8K helium volume from heat conducted from 300K and must be manufacturable at low cost. This report attempts to summarize the thermal and structural analysis leading to the selection of a candidate design for supports suitable for use in TESLA test cell cryostats.

DESIGN OVERVIEW

There are two conceptual designs being discussed with respect to support post mounting. One uses supports located on top of the vacuum vessel such that the cold mass hangs from the support. The second uses supports located on the bottom of the vacuum vessel such that the cold mass rests on the support. This second concept is the more conventional of the two options, however, in principal there is no reason that hanging the cold mass from the support poses any inherent installation or reliability problems. The advantage to the hanging concept is that it provides a readily accessible place from which to gather direct alignment data when the complete cryostat is installed in the test string. There are two substantive disadvantages. First, a cryostat with top-mounted supports requires reinforcing rings around the vacuum vessel at each support location to support the weight of the hanging assembly. Second, it moves the cavity centerline further from the fixed support base making it more sensitive to displacements occurring due to cooldown and to the action of external forces, e.g. forces acting through the input coupler. These effects will be discussed later in this report. Figures 1 and 2 illustrate the differences between these two design options. The cross section shown is that currently being developed at DESY and INFN.

There are also two conceptual designs being discussed with respect to the number of supports. One uses three supports as a means by which to minimize the cost of support assemblies and the cost of the vacuum vessel and thermal radiation shields. The other uses four supports to minimize axial contraction during cooldown. These latter two conceptual design differences have little effect on the analysis presented here, but will be discussed in more detail later in this report.

DESIGN ANALYSIS

There is little debate about the conceptual design of the support post itself. All of the design options being discussed utilize a single tube support developed as an alternative to the reentrant supports used in SSC collider dipole magnets.²⁻⁶ The single tube support was developed primarily to reduce magnet cost.

Figure 1. DESY Cross Section - Top Mounted Support

Figure 2. DESY Cross Section - Bottom Mounted Support

Thermal Path Length Optimization

The design of a TESLA cryostat support begins with a thermal analysis to determine the relative position of the thermal intercepts. There are intercepts at 300K, 70K, 4.5K, and 1.8K. The 300K and 1.8K positions are fixed at the ends of each support. The 70K and 4.5K intercept locations may be chosen anywhere along the length of the support. Their position is dictated by constraints on the allowable static heat load. For this analysis it is assumed that the goal is to minimize the refrigeration power required at room temperature. The heat load at each thermal intercept is translated into a corresponding refrigeration requirement at room temperature by using an expression for the ideal work defined by Carnot and a realistic refrigerator efficiency. The Carnot efficiency is given by the following.

$$\text{Carnot efficiency} = T / (300 - T) \quad [1]$$

where T is expressed in K.

Realistic refrigerator efficiencies are more difficult to estimate. Experiences at Fermilab, with the Tevatron refrigeration system, and at DESY, with the HERA system, indicate that reasonable refrigerator efficiencies are 20% at 70K and 4.5K and 10% at 1.8K. Combining these with the Carnot efficiencies results in the following room temperature loads. The results are expressed in watts per watt (W/W), e.g. 328 watts of power at room temperature are required to produce one watt of refrigeration at 4.5K.

Table 1. Room Temperature Refrigeration Requirements

T	Carnot eff	Refrig eff	Combined eff	r.t. W/W
70K	30.43%	20%	6.09%	16
4.5K	1.52%	20%	0.30%	328
1.8K	0.60%	10%	0.06%	1657

Figure 3 is a thermal model of a single tube support illustrating the pertinent analysis parameters. The optimal thermal path lengths (l) as fractions of the total support height are functions of the thermal intercept temperatures, material thermal conductivity, and tube cross sectional area (A). Ideally, there are thermal resistances at each intercept and at the cold mass connection. For the sake of this and subsequent analyses, these are assumed to be perfect connections. In reality, this assumption leads to a conservative result, i.e. actual heat loads, particularly to 1.8K are somewhat smaller than calculated values. The material assumed for the support is S-glass in an epoxy matrix. The thermal conductivity curve for this material is shown in figure 4. The dimension

nomenclature and the results from this analysis are shown in figures 5 and 6 respectively.

Figure 3. Single Tube Support Thermal Model

Figure 4. Support Post Material Thermal Conductivity vs. Temperature

Figure 5. Thermal Path Length Analysis Support Dimension Nomenclature

Figure 6. Thermal Path Length Analysis Results

Using figure 6, the minimum room temperature heat load occurs when L2, the 70K to 4.5K thermal path length, is 50% of the total thermal path length. This is the case when either L1 or L3 is held fixed. It is clear from figure 6 that the total room temperature heat load is rather insensitive to changes in L2 at its optimum, permitting relative freedom in positioning thermal intercepts as long as L2 is approximately 50% of the total thermal path length. This is especially true if L3 is fixed and only L1 and L2 are adjusted.

The path length optimization analysis also indicates that L3 should be as small as practical, approximately 5 mm for the support shown in figure 5. This is somewhat small when fabrication of the supports and subsequent assembly into the cryostat are considered. For mechanical attachment considerations, subsequent analyses will use 10 mm for L3, the thermal path length between 4.5K and 1.8K.

Detailed Thermal and Structural Analysis

The thermal path length optimization defines the position of thermal intercepts along the length of the support without regard for specified heat loads or structural requirements. The analysis of an actual support structure must consider the thermal and structural load constraints simultaneously. These are generally at odds with one another, that is low heat load implies low strength while high structural strength implies increased heat load. The budgeted heat loads and structural constraints are given in tables 2 and 3 respectively.¹

Table 2. Budgeted Heat Loads per Meter of Cryostat Length (W/m)

70K	4.5K	1.8K
0.5	0.2	0.05

Table 3. Structural Load Constraints

Load Direction	Load
Vertical	1.0 g
Lateral	1.0 g
Axial	1.8 g

Given the room temperature heat load conversions in table 1 and the budgeted heat loads in table 2, an equivalent room temperature heat load budget may be defined by the following.

$$Q_{r.t} = (0.5 \times 16) + (0.2 \times 328) + (0.05 \times 1657) = 156.45 \text{ W/m} \quad [2]$$

For a 12 meter long cryostat, this results in the following allowable heat loads per support.

Table 4. Budgeted Heat Loads per Support (W)

# of supports	70K	4.5K	1.8K	r.t. equivalent
3	2.00	0.80	0.20	626
4	1.50	0.60	0.15	469

The weights of all cold mass components are given in figures 1 and 2. These weights are estimated and include the GHe return pipe (560 kg), 70K and 4.5K shields (800 kg), 1.8K He vessels (400 kg), and RF cavity structures (340 kg). Weights for small components are included in the totals for each sub-system. There is an additional, estimated 140 kg quadrupole at one end of the cryostat assemble. The entire suspended cold mass weight is therefore 2240 kg. It is sufficiently accurate for the sake of this analysis to assume the weight is uniformly distributed among all supports. For the three and four support options, this results in the following lateral load per support.

Table 5. Lateral Loads per Support (kg)

# of supports	Lateral load (kg)
3	746.7
4	560.0

Using figures 1 and 2, the center of gravity of the cold mass assembly is nearly equidistant from the 1.8K surface of the post in both cases, 358 mm in the case of the top mounted support and 338 mm in the bottom mounted case. At this point in the design, there is enough uncertainty in the weights and final geometry to allow us to treat them as equal.

A physical envelope to limit the scope of the optimization study was chosen for the support post structure. Figure 7 illustrates the nomenclature used in the support post structural and thermal analysis. Table 6 lists all of the parameters and constraints used to define the dimensions for any particular analysis iteration. Note that the 70K to 4.5K thermal path length (L_{Thrm2}) is half the total thermal path length to *minimize* the room temperature heat load per the path length analysis above. The analysis program is capable of optimizing the wall thickness of each tube section, i.e. T1, T2, and T3 in figure 7. Ideally the tube can be machined with different thicknesses to take advantage of the decreasing bending stress along the support length. However, this has little effect on heat loads and decreases the lateral natural frequency of the support. Uniform wall thicknesses are assumed here to minimize machining cost on the complete assembly.

Overall height range	100 mm - 250 mm
Outside diameter range	150 mm - 300 mm
Wall thickness	Uniform to satisfy strength, safety factor = 2
300K and 1.8K flange thkns	20 mm
70K and 4.5K intercept thkns	10 mm
LThrm1 (300K-70K path len)	Height - 60 mm - LThrm2 - LThrm3
LThrm2 (70K-4.5K path len)	(Height - 60 mm) / 2
LThrm3 (4.5K-1.8K path len)	10 mm
L1	Height + 348 mm
L2	L1 - LThrm1 - 30 mm
L3	L2 - LThrm2 - 20 mm
L4	358 mm
Fg (lateral c.g. force)	746.7 kg (3 supports), 560.0 kg (4 supports)
W	-Fg

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Table 7. Support Post Material Thermal and Structural Properties

$\int k dT$ (300K-70K)	1.249 W/cm
$\int k dT$ (70K-4.5K)	0.146 W/cm
$\int k dT$ (4.5K-1.8K)	0.0015 W/cm
E (Young's modulus)	27.58 GPa
ν (Poisson's ratio)	0.2
G (Shear modulus)	2.62 GPa
s_{ult} (ultimate tensile and compressive strength)	275.8 MPa
t_{ult} (ultimate shear strength)	137.9 MPa

Thermal and Structural Analysis Results

Analyses were performed over the height and diameter ranges listed in table 6. The complete results for these analyses are shown in appendix A, table A-1 and figures A-1 through A-5 for the case of a cryostat with 3 supports and appendix B, table B-1 and figures B-1 through B-5 for the case using 4 supports. The analysis yields tube stresses, heat loads to 70K, 4.5K, and 1.8K, the equivalent room temperature refrigeration power required to meet these heat loads, the cold mass lateral deflection when subject to the lateral load (F_g), and an estimate of the lateral resonant frequency. Although not explicitly specified in the design requirements it is thought that the support resonant frequency should be above 10 Hz and below 25 Hz to minimize susceptibility to ground motion and electrically induced vibrations (50 Hz power) respectively. For this analysis a 12.5 to 18.75 Hz band has been defined within which the calculated resonance should fall. These values are 25% above and below the 10 Hz and 25 Hz limits respectively.

From tables A-1 and B-1 a total of five supports satisfy all of the above criteria, i.e. 70K, 4.5K, and 1.8K heat loads, structural constraints, and the constraint on resonant frequency. These are summarized in table 8 and shown in tables A-1 and B-1 in shaded, bold type.

Several things become clear when looking at the results shown in these tables and figures. The supports which satisfy all of the criteria outlined here tend to be larger than those in previous conceptual designs. Typical diameters have varied between 200 and 300 mm. Heights have varied between 100 and 190 mm. The larger diameters here are required to meet the proposed resonant frequency constraint. The greater heights are required to meet the heat load budget, given the increased diameters. Tube stresses are typically well below the allowable (defined as the ultimate strength derated by a safety factor of two). This is due to the fact that the governing structural criteria is elastic stability, i.e.

the tubes are sized to prevent local buckling of the material which occurs at stresses well below that causing tensile or compressive failure.^{3,4}

Table 8. Analysis Summary of Candidate Supports
(see appendices A and B for details)
(heat loads are per support)

# of supports	Height (mm)	Diameter (mm)	Q70 (W)	Q4.5 (W)	Q1.8 (W)	Q r.t. (W)	Nat freq (Hz)
3	220	275	1.96	0.20	0.02	130	12.5
3	230	300	1.93	0.20	0.02	130	12.9
3	240	300	1.82	0.19	0.02	125	12.6
4	240	275	1.50	0.16	0.02	103	12.6
4	250	300	1.49	0.16	0.02	105	13.1

These results also indicate that the specified heat loads to 70K, 4.5K, and 1.8K are not consistent with minimizing the room temperature heat load. For example, for the first entry in table 8, the calculated heat loads which meet the 70K, 4.5K, and 1.8K specifications and minimize room temperature heat load are 1.96 W to 70K, 0.20 W to 4.5K, and 0.02 W to 1.8K resulting in a room temperature load of 130 W, nearly a factor of five below the value listed in table 4. If minimized room temperature heat load is, in fact, a viable specification, it would help the design process to broaden the range of individual thermal station heat loads. One could then, for example, look for a design solution that results in a resonant frequency more toward the middle of the 12.5 to 18.75 Hz band, or define a stiffness specification in some other way. All of the cases presented in appendices A and B have room temperature heat loads below the budget shown in table 4, some with 70K heat loads five times the 70K budget.

As an example, suppose that, rather than the absolute limits on the 70K, 4.5K, and 1.8K heat loads in table 2, the specification were rewritten as shown in table 9.

Table 9. Alternate Specification for Budgeted Heat Loads per Meter of Cryostat Length (W/m)

70K	4.5K	1.8K
< 1.0	< 0.25	< 0.025

This results in a new set of specifications for the heat load per support shown in table 10.

**Table 10. Budgeted Heat Loads per Support (W)
Using Alternate Specification in Table 9**

# of supports	70K	4.5K	1.8K	r.t. equivalent
3	< 4.00	< 1.00	< 0.10	558 max
4	< 3.00	< 0.75	< 0.075	418 max

Even with all the above heat loads at their upper limit, the room temperature load is less than that given by equation [2] and listed in table 4. What this alternate specification does, however, is open up much of tables A-1 and B-1 for the selection of suitable support alternatives.

Top vs. Bottom Mounted Supports

As stated in the introduction to this report, there are no inherent difficulties with either top or bottom mounted supports from the standpoint of assembly or long term stability. Each has its merits and its drawbacks. There is however, one substantial difference, and that is in the deflection of the cavity centerline when subjected to external forces. Forces will act on the beam tube during cooldown by virtue of support from the gas helium tube and from thermal contraction which occurs in the input coupler. Although the magnitude is unknown, some relative differences can be calculated for each option. Figure 8 illustrates the beam tube centerline deflection for the support case highlighted in table A-1, page 3, and the cryostat dimensions in figures 1 and 2. Due to the distance the cavity lies from the support post base, the beam tube deflection in the top mounted case is more than a factor of two greater than in the bottom mounted case. Given the tight alignment tolerances required in the final installation, it seems that the design should strive for any alternatives which increase stiffness and thereby minimize deflections under the influence of outside forces.

SUMMARY

The analysis presented here is meant as a guide to the design of TESLA test cell cryostat supports. As in any complex device, there are many factors to be considered. Hopefully, most have been covered here, but some have been mentioned only briefly, e.g. alignment, cost, reliability, and ease of manufacture. Using criteria discussed throughout this report, a few conclusions can be drawn.

Figure 8. Load vs. Deflection for Top and Bottom Mounted Supports

First, assuming that minimizing the room temperature heat load is a viable basis for design development, the original heat load budgets to 70K, 4.5K, and 1.8K might warrant revision. Second, a firm specification on the suspension system lateral stiffness would be a useful means by which to assure a good overall design, not just one which meets the heat load budget. Third, thermally and structurally, there is no significant advantage to a cryostat using three or four supports. This is not surprising due to the fact that the structural and thermal analyses are largely linear. Cost and thermal contraction issues will likely play more significant roles in this choice. Finally, although potentially more practical in the alignment process, top mounted supports are probably not the best choice if one hopes to minimize lateral deflections of the cavity beam line during cooldown, alignment, and other operations which may subject the cavity or helium vessel to external forces.

The goal of this report has been to focus on issues critical to the development of a suspension system which addresses all of the pertinent design issues. Hopefully, it can serve as a guide for continued suspension system development and be useful as a tool to select or discount various conceptual design options.

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APPENDIX A

Thermal and Structural Analysis Results 3 Supports per Cryostat

TESLA Test Cell Support Analysis
3 supports per crystal
T.Nicol - Fermilab - August 1992

Refrigeration system		
W@T to W@T		
T (K)	eff	W/W
70	20%	16
4.5	20%	328
1.8	10%	1657

Heat load budget/support		
T (K)	Q (W)	Q r.f. (W)
70	2.00	33
4.5	0.80	263
1.8	0.20	331

Data for plotting budget values (per support)						
Ht (mm)	Q70 (W)	Q4.5 (W)	Q1.8 (W)	Q r.f. (W)	Nat f (Hz)	Nat f (Hz)
100	2.00	0.80	0.20	627	12.50	18.75
250	2.00	0.80	0.20	627	12.50	18.75

Ht (mm)	OD (mm)	L1 (mm)	L2 (mm)	L3 (mm)	L4 (mm)	LTH1 (mm)	LTH2 (mm)	LTH3 (mm)	T1 (mm)	T2 (mm)	T3 (mm)	Sig1 (MPa)	Sig2 (MPa)	Sig3 (MPa)	Q70 (W)	Q4.5 (W)	Q1.8 (W)	Q r.f. (W)	Fg (kg)	dv (mm)	Nat f (Hz)
100.0	150.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.702	1.702	1.702	122.4	113.5	106.0	9.285	0.563	0.012	357.4	746.6	1.135	14.8
110.0	150.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.702	1.702	1.702	123.6	113.6	104.9	6.176	0.453	0.012	270.4	746.6	1.420	13.2
120.0	150.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.727	1.727	1.727	124.9	113.8	103.9	4.640	0.379	0.012	221.0	746.6	1.709	12.1
130.0	150.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.753	1.753	1.753	126.2	113.9	102.9	3.726	0.327	0.012	189.0	746.6	2.002	11.1
140.0	150.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.753	1.753	1.753	127.4	114.0	101.9	3.121	0.287	0.013	166.3	746.6	2.299	10.4
150.0	150.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.778	1.778	1.778	128.6	114.2	101.0	2.691	0.256	0.013	149.2	746.6	2.601	9.8
160.0	150.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.803	1.803	1.803	129.9	114.4	100.0	2.370	0.231	0.013	136.1	746.6	2.908	9.2
170.0	150.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.803	1.803	1.803	131.1	114.5	99.2	2.121	0.211	0.013	125.6	746.6	3.221	8.8
180.0	150.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.829	1.829	1.829	132.3	114.7	98.3	1.922	0.194	0.013	116.8	746.6	3.538	8.4
190.0	150.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.854	1.854	1.854	133.4	114.9	97.4	1.760	0.180	0.013	109.5	746.6	3.861	8.0
200.0	150.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.854	1.854	1.854	134.6	115.0	96.6	1.625	0.168	0.013	103.6	746.6	4.191	7.7
210.0	150.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.880	1.880	1.880	135.8	115.2	95.8	1.511	0.157	0.013	98.3	746.6	4.526	7.4
220.0	150.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.905	1.905	1.905	136.9	115.4	95.0	1.414	0.147	0.013	93.7	746.6	4.867	7.1
230.0	150.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.905	1.905	1.905	137.9	115.5	94.1	1.331	0.139	0.014	89.9	746.6	5.204	6.9
240.0	150.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.956	1.956	1.956	137.9	114.7	92.6	1.268	0.133	0.014	87.2	746.6	5.512	6.7
250.0	150.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.981	1.981	1.981	137.9	114.0	91.2	1.212	0.127	0.014	84.7	746.6	5.822	6.5

100.0	175.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.575	1.575	1.575	97.4	90.5	84.5	10.082	0.612	0.013	388.1	746.6	0.841	17.2
110.0	175.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.600	1.600	1.600	98.4	90.5	83.7	6.706	0.492	0.013	293.5	746.6	1.049	15.4
120.0	175.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.600	1.600	1.600	99.4	90.6	82.9	5.037	0.412	0.013	239.9	746.6	1.262	14.0
130.0	175.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.626	1.626	1.626	100.4	90.7	82.1	4.045	0.355	0.013	204.9	746.6	1.478	13.0
140.0	175.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.626	1.626	1.626	101.3	90.8	81.3	3.387	0.311	0.014	180.3	746.6	1.697	12.1
150.0	175.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.651	1.651	1.651	102.3	91.0	80.6	2.920	0.278	0.014	161.9	746.6	1.915	11.4
160.0	175.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.676	1.676	1.676	103.3	91.1	79.8	2.572	0.251	0.014	147.4	746.6	2.139	10.8
170.0	175.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.676	1.676	1.676	104.2	91.2	79.1	2.301	0.229	0.014	136.0	746.6	2.367	10.2
180.0	175.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.702	1.702	1.702	105.1	91.3	78.4	2.085	0.211	0.014	126.7	746.6	2.596	9.8
190.0	175.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.702	1.702	1.702	106.1	91.5	77.8	1.909	0.195	0.014	118.8	746.6	2.830	9.4
200.0	175.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.727	1.727	1.727	107.0	91.6	77.1	1.763	0.182	0.014	112.3	746.6	3.066	9.0
210.0	175.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.753	1.753	1.753	107.9	91.7	76.5	1.639	0.170	0.015	106.7	746.6	3.307	8.7
220.0	175.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.753	1.753	1.753	108.8	91.9	75.9	1.533	0.160	0.015	101.7	746.6	3.551	8.4
230.0	175.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.778	1.778	1.778	109.7	92.0	75.3	1.441	0.151	0.015	97.2	746.6	3.800	8.1
240.0	175.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.778	1.778	1.778	110.6	92.2	74.7	1.361	0.143	0.015	93.6	746.6	4.054	7.8
250.0	175.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.803	1.803	1.803	111.5	92.4	74.1	1.290	0.136	0.015	90.4	746.6	4.310	7.6

Date: 8/13/92 Time: 8:22 Filename: Support analysis cases (s)

HI	OD	L1	L2	L3	L4	LTH1	LTH2	LTH3	T1	T2	T3	Sig1	Sig2	Sig3	Q10	Q1.5	Q1.8	Q1.9	Fg	dx	Nat f
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(MPa)	(MPa)	(MPa)	(W)	(W)	(W)	(W)	(kg)	(mm)	(Hz)
100.0	200.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.473	1.473	1.473	80.0	74.4	69.6	10.839	0.658	0.014	417.3	746.6	0.660	19.4
110.0	200.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.499	1.499	1.499	80.8	74.5	68.9	7.208	0.529	0.014	315.3	746.6	0.823	17.4
120.0	200.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.499	1.499	1.499	81.6	74.5	68.2	5.413	0.442	0.014	257.9	746.6	0.991	15.9
130.0	200.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.524	1.524	1.524	82.4	74.6	67.6	4.346	0.381	0.015	220.4	746.6	1.156	14.7
140.0	200.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.524	1.524	1.524	83.2	74.7	67.0	3.640	0.335	0.015	193.7	746.6	1.326	13.7
150.0	200.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.549	1.549	1.549	84.0	74.8	66.4	3.137	0.299	0.015	173.9	746.6	1.496	12.9
160.0	200.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.575	1.575	1.575	84.8	74.9	65.8	2.762	0.270	0.015	158.6	746.6	1.669	12.2
170.0	200.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.575	1.575	1.575	85.5	75.0	65.2	2.472	0.246	0.015	146.1	746.6	1.844	11.6
180.0	200.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.600	1.600	1.600	86.3	75.1	64.6	2.240	0.226	0.015	136.1	746.6	2.019	11.1
190.0	200.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.600	1.600	1.600	87.1	75.2	64.1	2.050	0.209	0.015	127.8	746.6	2.197	10.6
200.0	200.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.626	1.626	1.626	87.8	75.3	63.5	1.893	0.195	0.015	120.5	746.6	2.380	10.2
210.0	200.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.626	1.626	1.626	88.5	75.4	63.0	1.760	0.183	0.016	114.5	746.6	2.563	9.8
220.0	200.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.651	1.651	1.651	89.3	75.5	62.5	1.646	0.171	0.016	109.3	746.6	2.748	9.5
230.0	200.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.651	1.651	1.651	90.0	75.7	62.0	1.547	0.162	0.016	104.6	746.6	2.936	9.2
240.0	200.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.676	1.676	1.676	90.7	75.8	61.5	1.460	0.153	0.016	100.3	746.6	3.129	8.9
250.0	200.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.676	1.676	1.676	91.5	75.9	61.1	1.384	0.145	0.016	97.1	746.6	3.322	8.7

100.0	225.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.397	1.397	1.397	67.4	62.7	58.7	11.562	0.702	0.015	445.0	746.6	0.541	21.4
110.0	225.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.422	1.422	1.422	68.1	62.7	58.1	7.688	0.564	0.015	336.4	746.6	0.676	19.2
120.0	225.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.422	1.422	1.422	68.7	62.8	57.6	5.773	0.472	0.015	275.1	746.6	0.810	17.5
130.0	225.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.448	1.448	1.448	69.4	62.9	57.0	4.635	0.406	0.015	234.8	746.6	0.945	16.2
140.0	225.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.448	1.448	1.448	70.0	62.9	56.5	3.881	0.357	0.016	206.5	746.6	1.082	15.2
150.0	225.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.473	1.473	1.473	70.7	63.0	56.0	3.345	0.318	0.016	185.4	746.6	1.219	14.3
160.0	225.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.473	1.473	1.473	71.3	63.1	55.5	2.945	0.288	0.016	168.8	746.6	1.359	13.5
170.0	225.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.499	1.499	1.499	72.0	63.2	55.0	2.634	0.262	0.016	156.0	746.6	1.499	12.9
180.0	225.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.499	1.499	1.499	72.6	63.3	54.5	2.387	0.241	0.016	145.0	746.6	1.641	12.3
190.0	225.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.524	1.524	1.524	73.2	63.3	54.1	2.185	0.223	0.016	135.9	746.6	1.783	11.8
200.0	225.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.524	1.524	1.524	73.8	63.4	53.6	2.017	0.208	0.017	128.7	746.6	1.928	11.4
210.0	225.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.549	1.549	1.549	74.4	63.5	53.2	1.875	0.195	0.017	122.0	746.6	2.075	10.9
220.0	225.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.549	1.549	1.549	75.1	63.6	52.8	1.753	0.183	0.017	116.2	746.6	2.223	10.6
230.0	225.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.575	1.575	1.575	75.7	63.7	52.4	1.648	0.172	0.017	111.6	746.6	2.372	10.2
240.0	225.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.575	1.575	1.575	76.3	63.8	52.0	1.556	0.163	0.017	107.1	746.6	2.522	9.9
250.0	225.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.600	1.600	1.600	76.9	63.9	51.6	1.474	0.155	0.017	103.1	746.6	2.675	9.6

Hi	OD	L1	L2	L3	L4	L5	L6	L7	T1	T2	T3	Sig1	Sig2	Sig3	Q70	Q4.9	Q1.9	Q r.4	Pg	dx	Net f
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(MPa)	(MPa)	(MPa)	(W)	(W)	(W)	(W)	(kg)	(mm)	(Hz)
100.0	250.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.346	1.346	1.346	57.8	53.8	50.4	12.258	0.744	0.016	471.6	746.6	0.457	23.3
110.0	250.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.346	1.346	1.346	58.4	53.9	50.0	8.150	0.598	0.016	356.7	746.6	0.572	20.9
120.0	250.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.372	1.372	1.372	58.9	53.9	49.5	6.119	0.500	0.016	291.4	746.6	0.686	19.1
130.0	250.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.372	1.372	1.372	59.5	54.0	49.0	4.912	0.430	0.016	249.0	746.6	0.798	17.6
140.0	250.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.397	1.397	1.397	60.1	54.0	48.6	4.112	0.378	0.017	219.0	746.6	0.914	16.5
150.0	250.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.397	1.397	1.397	60.6	54.1	48.2	3.544	0.337	0.017	196.3	746.6	1.029	15.5
160.0	250.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.422	1.422	1.422	61.1	54.2	47.7	3.120	0.304	0.017	179.2	746.6	1.143	14.7
170.0	250.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.422	1.422	1.422	61.7	54.2	47.3	2.791	0.278	0.017	165.0	746.6	1.260	14.0
180.0	250.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.448	1.448	1.448	62.2	54.3	46.9	2.528	0.256	0.017	153.4	746.6	1.379	13.4
190.0	250.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.448	1.448	1.448	62.7	54.4	46.5	2.314	0.236	0.017	144.3	746.6	1.496	12.9
200.0	250.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.448	1.448	1.448	63.3	54.5	46.2	2.136	0.220	0.017	136.0	746.6	1.615	12.4
210.0	250.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.473	1.473	1.473	63.8	54.5	45.8	1.985	0.206	0.018	129.2	746.6	1.737	12.0
220.0	250.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.473	1.473	1.473	64.3	54.6	45.4	1.856	0.193	0.018	123.3	746.6	1.857	11.6
230.0	250.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.499	1.499	1.499	64.8	54.7	45.1	1.745	0.183	0.018	117.9	746.6	1.981	11.2
240.0	250.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.499	1.499	1.499	65.3	54.8	44.7	1.647	0.173	0.018	113.4	746.6	2.106	10.9
250.0	250.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.524	1.524	1.524	65.8	54.9	44.4	1.561	0.164	0.018	109.4	746.6	2.230	10.6

100.0	275.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.270	1.270	1.270	50.4	46.9	44.0	12.931	0.785	0.017	497.7	746.6	0.399	25.0
110.0	275.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.295	1.295	1.295	50.9	47.0	43.6	8.596	0.630	0.017	376.2	746.6	0.495	22.4
120.0	275.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.295	1.295	1.295	51.3	47.0	43.2	6.454	0.528	0.017	307.2	746.6	0.594	20.5
130.0	275.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.321	1.321	1.321	51.8	47.1	42.8	5.179	0.454	0.017	262.7	746.6	0.693	19.0
140.0	275.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.321	1.321	1.321	52.3	47.1	42.4	4.336	0.399	0.017	230.8	746.6	0.790	17.7
150.0	275.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.346	1.346	1.346	52.8	47.2	42.0	3.736	0.356	0.018	207.1	746.6	0.889	16.7
160.0	275.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.346	1.346	1.346	53.2	47.2	41.7	3.289	0.321	0.018	188.7	746.6	0.988	15.9
170.0	275.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.372	1.372	1.372	53.7	47.3	41.3	2.942	0.293	0.018	173.8	746.6	1.087	15.1
180.0	275.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.372	1.372	1.372	54.2	47.3	41.0	2.665	0.269	0.018	162.1	746.6	1.189	14.5
190.0	275.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.397	1.397	1.397	54.6	47.4	40.6	2.439	0.249	0.018	151.9	746.6	1.288	13.9
200.0	275.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.397	1.397	1.397	55.1	47.5	40.3	2.251	0.232	0.018	143.4	746.6	1.389	13.4
210.0	275.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.397	1.397	1.397	55.5	47.5	40.0	2.092	0.217	0.019	136.2	746.6	1.491	12.9
220.0	275.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.422	1.422	1.422	56.0	47.6	39.7	1.956	0.204	0.019	129.8	746.6	1.595	12.5
230.0	275.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.422	1.422	1.422	56.4	47.7	39.4	1.838	0.192	0.019	124.4	746.6	1.699	12.1
240.0	275.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.448	1.448	1.448	56.8	47.7	39.1	1.735	0.182	0.019	119.4	746.6	1.803	11.7
250.0	275.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.448	1.448	1.448	57.3	47.8	38.8	1.644	0.173	0.019	114.9	746.6	1.908	11.4

Hi	OD	L1	L2	L3	L4	L5	L6	L7	T1	T2	T3	Sig1	Sig2	Sig3	Q70	Q4.5	Q1.0	Q r.A	Fg	dx	Net f
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(MPa)	(MPa)	(MPa)	(W)	(W)	(W)	(W)	(kg)	(mm)	(Hz)
100.0	300.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.219	1.219	1.219	44.4	41.5	38.9	13.584	0.824	0.018	523.1	746.6	0.353	26.6
110.0	300.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.245	1.245	1.245	44.9	41.5	38.5	9.029	0.662	0.018	395.0	746.6	0.439	23.8
120.0	300.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.245	1.245	1.245	45.3	41.5	38.2	6.778	0.554	0.018	322.9	746.6	0.526	21.7
130.0	300.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.270	1.270	1.270	45.7	41.6	37.8	5.439	0.477	0.018	275.8	746.6	0.612	20.2
140.0	300.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.270	1.270	1.270	46.1	41.6	37.5	4.553	0.419	0.018	242.3	746.6	0.699	18.9
150.0	300.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.295	1.295	1.295	46.5	41.6	37.2	3.923	0.373	0.019	217.6	746.6	0.785	17.8
160.0	300.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.295	1.295	1.295	46.9	41.7	36.9	3.453	0.337	0.019	198.1	746.6	0.871	16.9
170.0	300.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.321	1.321	1.321	47.3	41.7	36.5	3.088	0.307	0.019	182.7	746.6	0.958	16.1
180.0	300.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.321	1.321	1.321	47.7	41.8	36.2	2.797	0.283	0.019	169.9	746.6	1.046	15.4
190.0	300.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.321	1.321	1.321	48.1	41.8	35.9	2.560	0.262	0.019	159.1	746.6	1.133	14.8
200.0	300.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.346	1.346	1.346	48.5	41.9	35.7	2.362	0.243	0.019	150.5	746.6	1.222	14.3
210.0	300.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.346	1.346	1.346	48.9	42.0	35.4	2.195	0.228	0.019	142.7	746.6	1.308	13.8
220.0	300.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.372	1.372	1.372	49.3	42.0	35.1	2.052	0.214	0.020	136.4	746.6	1.397	13.3
230.0	300.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.372	1.372	1.372	49.7	42.1	34.8	1.929	0.202	0.020	130.4	746.6	1.488	12.9
240.0	300.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.397	1.397	1.397	50.1	42.1	34.6	1.820	0.191	0.020	125.1	746.6	1.577	12.6
250.0	300.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.397	1.397	1.397	50.4	42.2	34.3	1.725	0.181	0.020	120.9	746.6	1.669	12.2

Figure A-1

Figure A-2

Figure A-3

Figure A-4

Figure A-5

APPENDIX B

Thermal and Structural Analysis Results 4 Supports per Cryostat

TESLA Test Cell Support Analysis
4 supports per crystal
T.Nicol - Fermilab - August 1992

Refrigeration System W&R.T. to W&T		
T (K)	eff	W/W
70	20%	16
4.5	20%	328
1.8	10%	1657

Heat Load Budget (W)		
T (K)	Q (W)	Q _{ext} (W)
70	1.50	25
4.5	0.60	197
1.8	0.15	249

Data for plotting budget values						
H _i (mm)	Q70 (W)	Q4.5 (W)	Q1.8 (W)	Q _{ext} (W)	Nat f (Hz)	Nat f (Hz)
100	1.50	0.60	0.15	470	12.50	18.75
250	1.50	0.60	0.15	470	12.50	18.75

Ht	OD	L1	L2	L3	L4	L1H	L1H2	L1H3	T1	T2	T3	Slg1	Slg2	Slg3	Q70	Q4.5	Q1.8	Qext	Fg	dx	Nat f
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(MPa)	(MPa)	(MPa)	(W)	(W)	(W)	(W)	(kg)	(mm)	(Hz)
100.0	150.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.473	1.473	1.473	105.7	98.1	91.6	8.036	0.488	0.010	309.3	559.9	0.978	15.9
110.0	150.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.473	1.473	1.473	106.8	98.2	90.6	5.345	0.392	0.010	233.8	559.9	1.224	14.3
120.0	150.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.499	1.499	1.499	107.9	98.3	89.8	4.016	0.328	0.011	191.3	559.9	1.473	13.0
130.0	150.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.499	1.499	1.499	109.0	98.4	88.9	3.225	0.283	0.011	163.4	559.9	1.727	12.0
140.0	150.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.524	1.524	1.524	110.1	98.5	88.1	2.701	0.248	0.011	143.8	559.9	1.984	11.2
150.0	150.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.549	1.549	1.549	111.1	98.7	87.2	2.329	0.222	0.011	129.2	559.9	2.245	10.5
160.0	150.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.549	1.549	1.549	112.2	98.8	86.4	2.051	0.200	0.011	117.7	559.9	2.512	10.0
170.0	150.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.575	1.575	1.575	113.2	98.9	85.7	1.836	0.183	0.011	108.7	559.9	2.781	9.5
180.0	150.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.575	1.575	1.575	114.3	99.1	84.9	1.664	0.168	0.011	101.0	559.9	3.056	9.0
190.0	150.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.600	1.600	1.600	115.3	99.2	84.2	1.523	0.156	0.011	95.0	559.9	3.335	8.6
200.0	150.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.600	1.600	1.600	116.3	99.4	83.5	1.406	0.145	0.011	89.6	559.9	3.620	8.3
210.0	150.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.626	1.626	1.626	117.3	99.6	82.8	1.308	0.136	0.012	85.2	559.9	3.909	8.0
220.0	150.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.626	1.626	1.626	118.3	99.7	82.1	1.223	0.128	0.012	81.2	559.9	4.204	7.7
230.0	150.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.651	1.651	1.651	119.3	99.9	81.5	1.150	0.120	0.012	77.9	559.9	4.503	7.4
240.0	150.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.676	1.676	1.676	120.3	100.1	80.8	1.086	0.114	0.012	74.8	559.9	4.808	7.2
250.0	150.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.676	1.676	1.676	121.3	100.2	80.2	1.030	0.108	0.012	72.0	559.9	5.118	7.0

100.0	175.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.372	1.372	1.372	84.2	78.2	73.1	8.727	0.529	0.011	336.1	559.9	0.724	18.5
110.0	175.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.372	1.372	1.372	85.1	78.3	72.3	5.804	0.426	0.011	254.0	559.9	0.907	16.6
120.0	175.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.397	1.397	1.397	85.9	78.4	71.6	4.360	0.356	0.012	207.8	559.9	1.090	15.1
130.0	175.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.397	1.397	1.397	86.8	78.4	70.9	3.501	0.307	0.012	177.5	559.9	1.275	14.0
140.0	175.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.422	1.422	1.422	87.6	78.5	70.3	2.932	0.270	0.012	156.2	559.9	1.466	13.0
150.0	175.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.422	1.422	1.422	88.4	78.6	69.6	2.528	0.241	0.012	140.1	559.9	1.656	12.3
160.0	175.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.448	1.448	1.448	89.3	78.7	69.0	2.226	0.217	0.012	127.8	559.9	1.849	11.6
170.0	175.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.448	1.448	1.448	90.1	78.8	68.4	1.992	0.198	0.012	118.0	559.9	2.045	11.0
180.0	175.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.473	1.473	1.473	90.9	78.9	67.8	1.805	0.182	0.012	109.7	559.9	2.243	10.5
190.0	175.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.473	1.473	1.473	91.7	79.1	67.2	1.653	0.169	0.012	102.8	559.9	2.446	10.1
200.0	175.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.499	1.499	1.499	92.5	79.2	66.7	1.526	0.157	0.012	97.2	559.9	2.652	9.7
210.0	175.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.499	1.499	1.499	93.3	79.3	66.1	1.418	0.147	0.013	92.4	559.9	2.858	9.3
220.0	175.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.524	1.524	1.524	94.1	79.4	65.6	1.327	0.138	0.013	88.1	559.9	3.071	9.0
230.0	175.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.524	1.524	1.524	94.8	79.6	65.1	1.247	0.131	0.013	84.2	559.9	3.284	8.7
240.0	175.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.549	1.549	1.549	95.6	79.7	64.5	1.178	0.124	0.013	81.1	559.9	3.503	8.4
250.0	175.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.549	1.549	1.549	96.4	79.8	64.0	1.116	0.117	0.013	78.4	559.9	3.726	8.2

Date: 8/13/22 Time: 8:25 Filename: Support analysis cases (sl)

Hi	OD	L1	L2	L3	L4	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	T26	T27	T28	T29	T30	T31	T32	T33	T34	T35	T36	T37	T38	T39	T40	T41	T42	T43	T44	T45	T46	T47	T48	T49	T50	T51	T52	T53	T54	T55	T56	T57	T58	T59	T60	T61	T62	T63	T64	T65	T66	T67	T68	T69	T70	T71	T72	T73	T74	T75	T76	T77	T78	T79	T80	T81	T82	T83	T84	T85	T86	T87	T88	T89	T90	T91	T92	T93	T94	T95	T96	T97	T98	T99	T100	T101	T102	T103	T104	T105	T106	T107	T108	T109	T110	T111	T112	T113	T114	T115	T116	T117	T118	T119	T120	T121	T122	T123	T124	T125	T126	T127	T128	T129	T130	T131	T132	T133	T134	T135	T136	T137	T138	T139	T140	T141	T142	T143	T144	T145	T146	T147	T148	T149	T150	T151	T152	T153	T154	T155	T156	T157	T158	T159	T160	T161	T162	T163	T164	T165	T166	T167	T168	T169	T170	T171	T172	T173	T174	T175	T176	T177	T178	T179	T180	T181	T182	T183	T184	T185	T186	T187	T188	T189	T190	T191	T192	T193	T194	T195	T196	T197	T198	T199	T200	T201	T202	T203	T204	T205	T206	T207	T208	T209	T210	T211	T212	T213	T214	T215	T216	T217	T218	T219	T220	T221	T222	T223	T224	T225	T226	T227	T228	T229	T230	T231	T232	T233	T234	T235	T236	T237	T238	T239	T240	T241	T242	T243	T244	T245	T246	T247	T248	T249	T250	T251	T252	T253	T254	T255	T256	T257	T258	T259	T260	T261	T262	T263	T264	T265	T266	T267	T268	T269	T270	T271	T272	T273	T274	T275	T276	T277	T278	T279	T280	T281	T282	T283	T284	T285	T286	T287	T288	T289	T290	T291	T292	T293	T294	T295	T296	T297	T298	T299	T300	T301	T302	T303	T304	T305	T306	T307	T308	T309	T310	T311	T312	T313	T314	T315	T316	T317	T318	T319	T320	T321	T322	T323	T324	T325	T326	T327	T328	T329	T330	T331	T332	T333	T334	T335	T336	T337	T338	T339	T340	T341	T342	T343	T344	T345	T346	T347	T348	T349	T350	T351	T352	T353	T354	T355	T356	T357	T358	T359	T360	T361	T362	T363	T364	T365	T366	T367	T368	T369	T370	T371	T372	T373	T374	T375	T376	T377	T378	T379	T380	T381	T382	T383	T384	T385	T386	T387	T388	T389	T390	T391	T392	T393	T394	T395	T396	T397	T398	T399	T400	T401	T402	T403	T404	T405	T406	T407	T408	T409	T410	T411	T412	T413	T414	T415	T416	T417	T418	T419	T420	T421	T422	T423	T424	T425	T426	T427	T428	T429	T430	T431	T432	T433	T434	T435	T436	T437	T438	T439	T440	T441	T442	T443	T444	T445	T446	T447	T448	T449	T450	T451	T452	T453	T454	T455	T456	T457	T458	T459	T460	T461	T462	T463	T464	T465	T466	T467	T468	T469	T470	T471	T472	T473	T474	T475	T476	T477	T478	T479	T480	T481	T482	T483	T484	T485	T486	T487	T488	T489	T490	T491	T492	T493	T494	T495	T496	T497	T498	T499	T500	T501	T502	T503	T504	T505	T506	T507	T508	T509	T510	T511	T512	T513	T514	T515	T516	T517	T518	T519	T520	T521	T522	T523	T524	T525	T526	T527	T528	T529	T530	T531	T532	T533	T534	T535	T536	T537	T538	T539	T540	T541	T542	T543	T544	T545	T546	T547	T548	T549	T550	T551	T552	T553	T554	T555	T556	T557	T558	T559	T560	T561	T562	T563	T564	T565	T566	T567	T568	T569	T570	T571	T572	T573	T574	T575	T576	T577	T578	T579	T580	T581	T582	T583	T584	T585	T586	T587	T588	T589	T590	T591	T592	T593	T594	T595	T596	T597	T598	T599	T600	T601	T602	T603	T604	T605	T606	T607	T608	T609	T610	T611	T612	T613	T614	T615	T616	T617	T618	T619	T620	T621	T622	T623	T624	T625	T626	T627	T628	T629	T630	T631	T632	T633	T634	T635	T636	T637	T638	T639	T640	T641	T642	T643	T644	T645	T646	T647	T648	T649	T650	T651	T652	T653	T654	T655	T656	T657	T658	T659	T660	T661	T662	T663	T664	T665	T666	T667	T668	T669	T670	T671	T672	T673	T674	T675	T676	T677	T678	T679	T680	T681	T682	T683	T684	T685	T686	T687	T688	T689	T690	T691	T692	T693	T694	T695	T696	T697	T698	T699	T700	T701	T702	T703	T704	T705	T706	T707	T708	T709	T710	T711	T712	T713	T714	T715	T716	T717	T718	T719	T720	T721	T722	T723	T724	T725	T726	T727	T728	T729	T730	T731	T732	T733	T734	T735	T736	T737	T738	T739	T740	T741	T742	T743	T744	T745	T746	T747	T748	T749	T750	T751	T752	T753	T754	T755	T756	T757	T758	T759	T760	T761	T762	T763	T764	T765	T766	T767	T768	T769	T770	T771	T772	T773	T774	T775	T776	T777	T778	T779	T780	T781	T782	T783	T784	T785	T786	T787	T788	T789	T790	T791	T792	T793	T794	T795	T796	T797	T798	T799	T800	T801	T802	T803	T804	T805	T806	T807	T808	T809	T810	T811	T812	T813	T814	T815	T816	T817	T818	T819	T820	T821	T822	T823	T824	T825	T826	T827	T828	T829	T830	T831	T832	T833	T834	T835	T836	T837	T838	T839	T840	T841	T842	T843	T844	T845	T846	T847	T848	T849	T850	T851	T852	T853	T854	T855	T856	T857	T858	T859	T860	T861	T862	T863	T864	T865	T866	T867	T868	T869	T870	T871	T872	T873	T874	T875	T876	T877	T878	T879	T880	T881	T882	T883	T884	T885	T886	T887	T888	T889	T890	T891	T892	T893	T894	T895	T896	T897	T898	T899	T900	T901	T902	T903	T904	T905	T906	T907	T908	T909	T910	T911	T912	T913	T914	T915	T916	T917	T918	T919	T920	T921	T922	T923	T924	T925	T926	T927	T928	T929	T930	T931	T932	T933	T934	T935	T936	T937	T938	T939	T940	T941	T942	T943	T944	T945	T946	T947	T948	T949	T950	T951	T952	T953	T954	T955	T956	T957	T958	T959	T960	T961	T962	T963	T964	T965	T966	T967	T968	T969	T970	T971	T972	T973	T974	T975	T976	T977	T978	T979	T980	T981	T982	T983	T984	T985	T986	T987	T988	T989	T990	T991	T992	T993	T994	T995	T996	T997	T998	T999	T1000	T1001	T1002	T1003	T1004	T1005	T1006	T1007	T1008	T1009	T1010	T1011	T1012	T1013	T1014	T1015	T1016	T1017	T1018	T1019	T1020	T1021	T1022	T1023	T1024	T1025	T1026	T1027	T1028	T1029	T1030	T1031	T1032	T1033	T1034	T1035	T1036	T1037	T1038	T1039	T1040	T1041	T1042	T1043	T1044	T1045	T1046	T1047	T1048	T1049	T1050	T1051	T1052	T1053	T1054	T1055	T1056	T1057	T1058	T1059	T1060	T1061	T1062	T1063	T1064	T1065	T1066	T1067	T1068	T1069	T1070	T1071	T1072	T1073	T1074	T1075	T1076	T1077	T1078	T1079	T1080	T1081	T1082	T1083	T1084	T1085	T1086	T1087	T1088	T1089	T1090	T1091	T1092	T1093	T1094	T1095	T1096	T1097	T1098	T1099	T1100	T1101	T1102	T1103	T1104	T1105	T1106	T1107	T1108	T1109	T1110	T1111	T1112	T1113	T1114	T1115	T1116	T1117	T1118	T1119	T1120	T1121	T1122	T1123	T1124	T1125	T1126	T1127	T1128	T1129	T1130	T1131	T1132	T1133	T1134	T1135	T1136	T1137	T1138	T1139	T1140	T1141	T1142	T1143	T1144	T1145	T1146	T1147	T1148	T1149	T1150	T1151	T1152	T1153	T1154	T1155	T1156	T1157	T1158	T1159	T1160	T1161	T1162	T1163	T1164	T1165	T1166	T1167	T1168	T1169	T1170	T1171	T1172	T1173	T1174	T1175	T1176	T1177	T1178	T1179	T1180	T1181	T1182	T1183	T1184	T1185	T1186	T1187	T1188	T1189	T1190	T1191	T1192	T1193	T1194	T1195	T1196	T1197	T1198	T1199	T1200	T1201	T1202	T1203	T1204	T1205	T1206	T1207	T1208	T1209	T1210	T1211	T1212	T1213	T1214	T1215	T1216	T1217	T1218	T1219	T1220	T1221	T1222	T1223	T1224	T1225	T1226	T1227	T1228	T1229	T1230	T1231	T1232	T1233	T1234	T1235	T1236	T1237	T1238	T1239	T1240	T1241	T1242	T1243	T1244	T1245	T1246	T1247	T1248	T1249	T1250	T1251	T1252	T1253	T1254	T1255	T1256	T1257	T1258	T1259	T1260	T1261	T1262	T1263	T1264	T1265	T1266	T1267	T1268	T1269	T1270	T1271	T1272	T1273	T1274	T1275	T1276	T1277	T1278	T1279	T1280	T1281	T1282	T1283	T1284	T1285	T1286	T1287	T1288	T1289	T1290	T1291	T1292	T1293	T1294	T1295	T1296	T1297	T1298	T1299	T1300	T1301	T1302	T1303	T1304	T1305	T1306	T1307	T1308	T1309	T1310	T1311	T1312	T1313	T1314	T1315	T1316	T1317	T1318	T1319	T1320	T1321	T1322	T1323	T1324	T1325	T1326	T1327	T1328	T1329	T1330	T1331	T1332	T1333	T1334	T1335	T1336	T1337	T1338	T1339	T1340	T1341	T1342	T1343	T1344	T1345	T1346	T1347	T1348	T1349	T1350	T1351	T1352	T1353	T1354	T1355	T1356	T1357	T1358	T1359	T1360	T1361	T1362	T1363	T1364	T1365	T1366	T1367	T1368	T1369	T1370	T1371	T1372	T1373	T1374	T1375	T1376	T1377	T1378	T1379	T1380	T1381	T1382	T1383	T1384	T1385	T1386	T1387	T1388	T1389	T1390	T1391	T1392	T1393	T1394	T1395	T1396	T1397	T1398	T1399	T1400	T1401	T1402	T1403	T1404	T1405	T1406	T1407	T1408	T1409	T1410	T1411	T1412	T1413	T1414	T1415	T1416	T1417	T1418	T1419	T1420	T1421	T1422	T1423	T1424	T1425	T1426	T1427	T1428	T1429	T1430	T1431	T1432	T1433	T1434	T1435	T1436	T1437	T1438	T1439	T1440	T1441	T1442	T1443	T1444	T1445	T1446	T1447	T1448	T1449	T1450	T1451	T1452	T1453	T1454	T1455	T1456	T1457	T1458	T1459	T1460	T1461	T1462	T1463	T1464	T1465	T1466	T1467	T1468	T1469	T1470	T1471	T1472	T1473	T1474	T1475	T1476	T1477	T1478	T1479	T1480	T1481	T1482	T1483	T1484	T1485
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Date: 8/13/02 Time: 8:25 Filename: Support analysis cases (sl)

Hi	OD	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
100.0	250.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.143	1.143	1.143	50.0	46.6	43.6	10.613	0.644	0.014	408.5	559.9	0.396	25.1
110.0	250.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.168	1.168	1.168	50.5	46.6	43.2	7.056	0.518	0.014	308.5	559.9	0.493	22.4
120.0	250.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.168	1.168	1.168	51.0	46.7	42.8	5.298	0.433	0.014	252.2	559.9	0.592	20.5
130.0	250.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.194	1.194	1.194	51.5	46.7	42.4	4.252	0.373	0.014	215.6	559.9	0.691	19.0
140.0	250.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.194	1.194	1.194	52.0	46.8	42.0	3.560	0.327	0.014	189.3	559.9	0.790	17.7
150.0	250.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.219	1.219	1.219	52.4	46.8	41.7	3.068	0.292	0.014	170.0	559.9	0.889	16.7
160.0	250.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.219	1.219	1.219	52.9	46.9	41.3	2.701	0.264	0.015	154.9	559.9	0.991	15.8
170.0	250.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.219	1.219	1.219	53.4	46.9	40.9	2.416	0.241	0.015	142.7	559.9	1.090	15.1
180.0	250.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.245	1.245	1.245	53.8	47.0	40.6	2.189	0.221	0.015	132.9	559.9	1.191	14.4
190.0	250.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.245	1.245	1.245	54.3	47.0	40.3	2.004	0.205	0.015	124.8	559.9	1.295	13.9
200.0	250.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.270	1.270	1.270	54.7	47.1	39.9	1.849	0.191	0.015	117.6	559.9	1.397	13.3
210.0	250.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.270	1.270	1.270	55.2	47.2	39.6	1.719	0.178	0.015	111.8	559.9	1.501	12.9
220.0	250.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.295	1.295	1.295	55.6	47.2	39.3	1.607	0.168	0.015	106.7	559.9	1.608	12.4
230.0	250.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.295	1.295	1.295	56.1	47.3	39.0	1.510	0.158	0.015	102.1	559.9	1.715	12.0
240.0	250.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.295	1.295	1.295	56.5	47.4	38.7	1.426	0.150	0.016	98.2	559.9	1.821	11.7
250.0	250.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.321	1.321	1.321	56.9	47.5	38.4	1.351	0.142	0.016	94.8	559.9	1.930	11.4

100.0	275.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.118	1.118	1.118	43.6	40.6	38.1	11.196	0.679	0.015	431.0	559.9	0.343	26.9
110.0	275.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.118	1.118	1.118	44.0	40.7	37.7	7.442	0.546	0.015	325.5	559.9	0.429	24.1
120.0	275.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.118	1.118	1.118	44.4	40.7	37.4	5.588	0.457	0.015	266.1	559.9	0.513	22.0
130.0	275.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.143	1.143	1.143	44.8	40.7	37.0	4.484	0.393	0.015	227.4	559.9	0.599	20.4
140.0	275.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.143	1.143	1.143	45.2	40.8	36.7	3.754	0.345	0.015	199.7	559.9	0.683	19.1
150.0	275.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.168	1.168	1.168	45.7	40.8	36.4	3.235	0.308	0.015	179.2	559.9	0.770	18.0
160.0	275.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.168	1.168	1.168	46.1	40.9	36.1	2.847	0.278	0.015	163.4	559.9	0.856	17.0
170.0	275.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.168	1.168	1.168	46.5	40.9	35.8	2.547	0.254	0.015	150.5	559.9	0.942	16.3
180.0	275.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.194	1.194	1.194	46.9	41.0	35.5	2.307	0.233	0.016	140.1	559.9	1.029	15.6
190.0	275.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.194	1.194	1.194	47.2	41.0	35.2	2.112	0.216	0.016	131.5	559.9	1.115	14.9
200.0	275.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.219	1.219	1.219	47.6	41.1	34.9	1.949	0.201	0.016	124.0	559.9	1.204	14.4
210.0	275.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.219	1.219	1.219	48.0	41.1	34.6	1.811	0.188	0.016	117.8	559.9	1.290	13.9
220.0	275.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.219	1.219	1.219	48.4	41.2	34.3	1.693	0.177	0.016	112.4	559.9	1.379	13.4
230.0	275.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.245	1.245	1.245	48.8	41.2	34.1	1.591	0.167	0.016	107.5	559.9	1.471	13.0
240.0	275.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.245	1.245	1.245	49.2	41.3	33.8	1.502	0.158	0.016	103.4	559.9	1.560	12.6
250.0	275.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.270	1.270	1.270	49.5	41.4	33.6	1.423	0.150	0.017	99.8	559.9	1.651	12.3

Ht	OD	L1	L2	E	PC	STX	STY2	STY3	T1	T2	T3	Sig1	Sig2	Sig3	Q70	Q45	Q15	Q r.s.	Fg	dx	Nat.f
(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(MPa)	(MPa)	(MPa)	(W)	(W)	(W)	(W)	(kg)	(mm)	(Hz)
100.0	300.0	448.0	413.0	383.0	358.0	10.0	20.0	10.0	1.067	1.067	1.067	38.5	35.9	33.7	11.762	0.714	0.015	452.8	559.9	0.305	28.5
110.0	300.0	458.0	418.0	383.0	358.0	15.0	25.0	10.0	1.067	1.067	1.067	38.8	35.9	33.4	7.818	0.573	0.015	342.0	559.9	0.381	25.6
120.0	300.0	468.0	423.0	383.0	358.0	20.0	30.0	10.0	1.092	1.092	1.092	39.2	35.9	33.0	5.869	0.480	0.016	279.6	559.9	0.455	23.4
130.0	300.0	478.0	428.0	383.0	358.0	25.0	35.0	10.0	1.092	1.092	1.092	39.5	36.0	32.7	4.710	0.413	0.016	238.9	559.9	0.531	21.7
140.0	300.0	488.0	433.0	383.0	358.0	30.0	40.0	10.0	1.118	1.118	1.118	39.9	36.0	32.5	3.942	0.362	0.016	209.8	559.9	0.605	20.3
150.0	300.0	498.0	438.0	383.0	358.0	35.0	45.0	10.0	1.118	1.118	1.118	40.3	36.0	32.2	3.397	0.323	0.016	188.3	559.9	0.678	19.1
160.0	300.0	508.0	443.0	383.0	358.0	40.0	50.0	10.0	1.118	1.118	1.118	40.6	36.1	31.9	2.989	0.292	0.016	171.6	559.9	0.754	18.2
170.0	300.0	518.0	448.0	383.0	358.0	45.0	55.0	10.0	1.143	1.143	1.143	41.0	36.1	31.6	2.674	0.266	0.016	158.0	559.9	0.831	17.3
180.0	300.0	528.0	453.0	383.0	358.0	50.0	60.0	10.0	1.143	1.143	1.143	41.3	36.2	31.4	2.422	0.245	0.016	147.1	559.9	0.904	16.6
190.0	300.0	538.0	458.0	383.0	358.0	55.0	65.0	10.0	1.143	1.143	1.143	41.6	36.2	31.1	2.216	0.226	0.017	138.0	559.9	0.980	15.9
200.0	300.0	548.0	463.0	383.0	358.0	60.0	70.0	10.0	1.168	1.168	1.168	42.0	36.3	30.9	2.045	0.211	0.017	130.1	559.9	1.057	15.3
210.0	300.0	558.0	468.0	383.0	358.0	65.0	75.0	10.0	1.168	1.168	1.168	42.3	36.3	30.6	1.901	0.197	0.017	123.6	559.9	1.133	14.8
220.0	300.0	568.0	473.0	383.0	358.0	70.0	80.0	10.0	1.194	1.194	1.194	42.7	36.4	30.4	1.777	0.185	0.017	118.0	559.9	1.209	14.3
230.0	300.0	578.0	478.0	383.0	358.0	75.0	85.0	10.0	1.194	1.194	1.194	43.0	36.4	30.1	1.670	0.175	0.017	112.8	559.9	1.288	13.9
240.0	300.0	588.0	483.0	383.0	358.0	80.0	90.0	10.0	1.194	1.194	1.194	43.3	36.5	29.9	1.576	0.165	0.017	108.8	559.9	1.367	13.5
250.0	300.0	598.0	488.0	383.0	358.0	85.0	95.0	10.0	1.219	1.219	1.219	43.7	36.5	29.7	1.493	0.157	0.017	104.7	559.9	1.443	13.1

Figure B-1

Figure B-2

Figure B-3

Figure B-4

Figure B-5